Edition 3 by David A. Rosenthal

HOW TO USE GEOPHYSICAL ALERT BROADCASTS

Preface

This User's Guide is primarily based on information made available by the United States National Oceanic and Atmospheric Administration's Space Environment Services Center in Boulder, Colorado. The Geophysical Alert Broadcasts are primarily intended for users in North America and the Pacific since that region is where radio stations WWV and WWVH are best received. However, data contained in the broadcasts are useful worldwide and propagation conditions can be such that either or both of these stations can be received surprisingly well throughout the planet.

There are other sources of solar geophysical data too. Mike Bird offers a weekly overview of conditions, together with a forecast, each Thursday on Radio Netherlands. This appears during the Media Network programme, and is now also available on this Web site.

The geomagnetic conditions as reported in the Radio Netherlands broadcasts are most representative of conditions in mid-northern latitudes but reports of solar activity are easily applicable elsewhere.

We would like to express our thanks and appreciation to the people at the Space Environment Services Center for their cooperation and assistance in the production of this User's Guide.

Comments and suggestions **concerning this User's Guide only** are always welcome direct to the author.

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One of the handiest (and cheapest) methods to better understand the current state of shortwave radio propagation conditions is by monitoring the Geophysical Alert Broadcasts made at 18 minutes past each hour over the U. S. National Institute of Standards and Technology radio station WWV in Ft. Collins, Colorado and at 45 minutes past each hour via WWHV on the island of Kauai in Hawaii WWV broadcasts continuously on shortwave frequencies of 2.5, 5, 10, 15, and 20 MHz and WWVH broadcasts on 2.5, 5, 10 and 15 MHz. Their signals are audible throughout North America and the Pacific Region and often the rest of the world, depending upon radio propagation conditions.

These 45-second Geophysical Alert Broadcasts outline the current nature of the solar-terrestrial environment. They are produced by the National Oceanic and Atmospheric Administration's Space Environment Services Center (SESC). This center operates a worldwide network of sensors which continuously observe conditions between the earth and the sun. A listener familiar with the types of information presented can gain a surprising amount of insight into how the natural phenomena primarily responsible for long-distance HF radio communication are currently affecting it at the moment as well as in the near future.

Updated every three-hours beginning at 0000 UTC, the Geophysical Alert Broadcasts are concerned with two primary types of Earth-sun interaction: electromagnetic radiation and geomagnetic activity (which includes effects from solar sub-atomic particle emissions).The effects of each are summarized below:

Electromagnetic Radiation

The sun's electromagnetic spectrum is a continuum of radiation spanning not only infrared, visible, and ultraviolet wavelengths, but the radio portions, x-rays and beyond. Sensors on the Earth and in space continuously observe specific portions of the sun's energy spectrum to monitor their levels and give scientists indications of when significant events occur.

Solar emissions in this category are all electromagnetic in nature, that is, they move at the speed of light. Events detected on the sun in these wavelengths begin to affect the Earth's environment around 8 minutes after they occur.

Geomagnetic Activity

In addition to electromagnetic radiation, the sun constantly ejects matter in the form of atomic and subatomic particles. Consisting typically of electrons, protons, and helium nuclei, this tenuous gas is accelerated to speeds in excess of the sun's gravitational escape velocity and thus moves outward into the solar system. The collective term for the gas and the particles making them up is the Solar Wind. The sun's approximately 27-day rotation period results in the clouds being slung outward in an expanding spiral pattern which, at the earth-sun distance, overtakes the earth from behind as it moves along in it's orbit.

As the clouds encounter the earth, the geomagnetic field and the earth's atmosphere prevents the solar wind particles from striking the planet directly. Magnetic interactions between the clouds and the geomagnetic field cause the solar wind particles to flow around the field, forming a shell-like hollow with the earth at the center. The hollow, known as the earth's **Magnetosphere**, is actually distorted into a comet shape with the head of the comet always pointing directly into the solar wind and the tail directly away. In the absence of significant solar activity, the solar wind is uniform with a velocity of approximately 400 km/second. Under these conditions, the earth's magnetosphere maintains a fairly steady shape and orientation in space.

When disturbances occur on the sun, some clouds of solar particles can be blasted away at tremendous velocities. As these higher speed solar particle clouds encounter the earth's magnetosphere, they perturb it, changing the intensity and direction of the earth's magnetic field. This is analogous to a weather vane in gusty wind; sudden higher speed gusts can strike it and cause it to move around. Moreover, changes in solar wind density and velocity can cause the Earthìs surface and are referred to as a "sudden impulse" (SI).

Geomagnetic activity, including solar particle-caused variations in the geomagnetic field are carefully monitored by instruments both on the Earth and in space. High levels of geomagnetic activity act indirectly to degrade the ability of the ionosphere to propagate HF radio signals. So they are of interest to users of that portion of the radio frequency spectrum. Like the electromagnetic radiation portions of the sun's output, geomagnetic activity comprises another family of interactions observed and reported by groups such as IPS and SESC.

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The Geophysical Alert Broadcasts consist of three primary sections to describe the Solar-terrestrial environment: The most current information, then a summary of activity for the past 24 hours, and finally a forecast for the next 24 hours. The actual wording of each section of the broadcast is explained below with a brief description of what is being reported. Similar wording is also used in other broadcasts, so the WWV example is relevant to other reports too.

Current Information

'Solar-terrestrial indices for (UTC Date) follow: Solar flux (number) and (estimated) Boulder A index (number) . Repeat, solar flux (number) and (estimated) Boulder A index (number) . The Boulder K index at (UTC time) on (UTC Date) was (number) repeat (number) .'

Since the final A index is not available until 0000 UTC, the word 'estimated' is used for the 1800 and 2100 UTC announcements.

Solar Flux

Solar Flux is a measurement of the intensity of solar radio emissions at a frequency of 2800 MHz made using a radio telescope located in Ottawa, Canada. Known also as the 10.7 cm flux (the wavelength of the radio signals at 2800 MHz), this solar radio emission has been shown to be proportional to sunspot activity. In addition, the level of the sun's ultraviolet and X-ray emissions is primarily responsible for causing ionization in the earth's upper atmosphere. It is these emissions which produce the ionized 'layers' involved in propagating shortwave radio signals over long distances.

The solar flux number reported in the broadcast is in solar flux units (s. f. u.) and is recorded daily at Ottawa at 1700 UTC to be forwarded to the SESC. Solar flux readings range from a theoretical minimum of approximately 67 to actually-observed numbers greater than 300. Low solar flux numbers dominate during the lower portions of the 11-year sunspot cycle, rising as the cycle proceeds with the average solar flux a fairly reliable indicator of the cycle's long-term behavior. 1 s. f. u. = 10^{-22}Watt/(meter^2·Hz) = 10^4 jansky.

A Index

The A Index is an averaged quantitative measure of geomagnetic activity derived from a series of physical measurements. Magnetometers measure differences between the current orientation of the magnetosphere and compare it to what it would be under 'quiet' geomagnetic conditions.

But there is more to understanding the meaning of the Boulder A index reported in the Geophysical Alert Broadcasts. The Boulder A index in the announcement is the 24 hour A index derived from the eight 3-hour K indices recorded at Boulder. The first estimate of the Boulder A index is at 1800 UTC. This estimate is made using the six observed Boulder K indices available at that time (0000 to 1800 UTC) and the SESC forecaster's best prediction for the remaining two K indices. To make those predictions, SESC forecasters examine present trends and other geomagnetic indicators. At 2100 UTC, the next observed Boulder K index is measured and the estimated A index is reevaluated and updated if necessary. At 0000 UTC, the eighth and last Boulder K index is measured and the actual Boulder A index is produced. For the 0000 UTC announcement and all subsequent announcements the word 'estimated' is dropped and the actual Boulder A index is used.

The underlying concept of the A index is to provide a longer-term picture of geomagnetic activity using measurements ***averaged*** either over some time frame or from a range of stations over the globe (or both). Numbers presented as A indices are the result of a several-step process: first, a magnetometer reading is taken to produce a K index for that station *(see K INDEX below)*; the K index is adjusted for the station's geographical location to produce an **a index** (no typographical error here, it is a small case 'a') for that 3-hour period; and finally a collection of a indices is averaged to produce an overall A index for the timeframe or region of interest.

A and **a** indices range in value from 0 to 400 and are derived from K-indices based on the table of equivalents shown in the APPENDIX.

K Index

The K index is the result of a 3-hourly magnetometer measurement comparing the current geomagnetic field orientation and intensity to what it would have been under geomagnetically 'quiet' conditions. K index measurements are made at sites throughout the globe and each is carefully adjusted for the geomagnetic characteristics of its locality. The scale used is quasi logarithmic, increasing as the geomagnetic field becomes more disturbed. K indices range in value from 0 to 9.

In the Geophysical Alert Broadcasts, the K index used is usually derived from magnetometer measurements made at the Table Mountain Observatory located just north of Boulder, Colorado. Every 3 hours new K indices are determined and the broadcasts are updated.

Conditions for the Past 24 hours

'Solar-terrestrial conditions for the last 24 hours follow:
Solar activity was (Very low, Low, Moderate, High, or Very high) ,
the geomagnetic field was (Quiet, Unsettled, Active, Minor storm, Major storm, Severe storm) .'

Solar Activity

Solar activity is a measure of energy releases in the solar atmosphere, generally observed by X-ray detectors on earth-orbiting satellites. Somewhat different from longer-term Solar Flux measurements, Solar Activity data provide an overview of X-ray emissions that exceed prevailing levels. The five standard terms listed correspond to the following levels of enhanced X-ray emissions observed or predicted within a 24-hour period:

Very Low	X-ray events less than C-class.
Low	C-class x-ray events.
Moderate	Isolated (1 to 4) M-class x-ray events.
High	Several (5 or more) M-class x-ray events, or isolated (1 to 4) M5 or greater x-ray events.
Very High	Several (5 or more) M5 or greater x-ray events.

The x-ray event classes listed correspond to a standardized method of classification based on the peak flux of the x-ray emissions as measured by detectors. Solar x-rays occupy a wide range of wavelengths with the portion used for flare classification from 0.1 through 0.8 nm. The classification scheme ranges in increasing x-ray peak flux from B-class events, through C- and M-class, to X-class events at the highest end (see APPENDIX).

In the Geophysical Alert Broadcasts, solar activity data provides an overview of x-ray emissions which might have effects on the quality of shortwave radio propagation. Large solar x-ray outbursts can produce sudden and extensive ionization in the lower regions of the earth's ionosphere which can rapidly increase shortwave signal absorption there. Occurring on the sun-facing side of the Earth, these **sudden ionospheric disturbances** are known as '**shortwave fadeouts**' and can degrade short wave communications for from minutes to hours.

They are characterized by the initial disappearance of signals on lower frequencies with subsequent fading up the frequency spectrum over a short period (usually less than a hour). Daytime HF communication disruptions due to high solar activity are more common during the years surrounding the peak of the solar cycle. The sun rotates once approximately every 27 days, often carrying active regions on its surface to where they again face the Earth; periods of disruption can recur at about this interval as a result.

Rule of Thumb: The higher the solar activity, the better the conditions on the higher frequencies (i.e. 15, 17, 21, and 25 MHz). During a solar X-ray outburst, the lower frequencies are the first to suffer. Remember too that that signals crossing daylight paths will be the most affected. If you hear

announcements on broadcast radio stations (e.g. Radio Netherlands) or via WWV/WWVH of such a solar disturbance try tuning to a HIGHER frequency. Higher frequencies are also the first to recover after a storm. Note that this is the opposite to disturbances indirectly caused by geomagnetic storms.

Geomagnetic Activity
As an overall assessment of natural variations in the geomagnetic field, six standard terms are used in reporting geomagnetic activity. The terminology is based on the estimated A index for the 24-hour period directly preceding the time the broadcast was last updated:

Category	**Range of A-index**
Quiet	0-7
Unsettled	8-15
Active	16-29
Minor storm	30-49
Major storm	50-99
Severe storm	100-400

These standardized terms correspond to the range of a and A indices previously explained in the A INDEX section. Increasing geomagnetic activity corresponds to more and greater perturbations of the geomagnetic field as a result of variations in the solar wind and more energetic solar particle emissions.

Using the earlier analogy, imagine the geomagnetic field to be like a weather vane in an increasingly violent windstorm. As the winds increase, the weather vane is continually buffeted by gusts and oscillates about the direction of the prevailing wind. Essentially, the reported geomagnetic activity category corresponds to how violently the geomagnetic field is being knocked about.

For shortwave radio spectrum users, high geomagnetic activity tends to degrade the quality of communications because geomagnetic field disturbances also diminish the capabilities of the ionosphere to propagate radio signals. In and near the auroral zone, absorption of radio energy in the ionosphereìs D region (about 80 km high) can increase dramatically , especially in the lower portions of the HF band. Signals passing through these regions can become unusable.

Geomagnetic disturbances in the middle latitudes can decrease the density of electrons in the ionosphere and thus the maximum radio frequency the region will propagate. Extended periods of geomagnetic activity known as **geomagnetic storms** can last for days. The impact on radio propagation during the storm depends on the level of solar flux and the severity of the geomagnetic field disturbance.

During some geomagnetic storms, worldwide disruptions of the ionosphere are possible. Called **ionospheric storms,** short wave propagation via the ionosphereìs F region (about 300 km high) can be affected. Here, middle latitude propagation can be diminished while propagation at low latitudes is improved. Ionospheric storms may or may not accompany geomagnetic activity, depending on the severity of the activity, its recent history, and the level of the solar flux.

Rule of thumb: Oversimplification is dangerous in the complex field of propagation. We know much less about the 'radio weather' than ordinary weather. In general though, for long distance medium-wave listening, the A index should be under 14, and the solar activity low-moderate. If the A-index drops under 7 for a few days in a row (usually during sunspot minimum conditions) look out for really excellent intercontinental conditions (e.g. trans Atlantic reception).

During minor geomagnetic storms, signals from the equatorial regions of the world are least affected. On the 60 and 90 metre tropical bands you can expect interference from utility stations in Europe/North America/Australia to be lower. Sometimes, this means that weaker signals from the tropics can get through, albeit they may suffer fluttery fading. Signals on the higher frequencies fade out first during a geomagnetic storm. Signals that travel anywhere near the North or South Pole may disappear or suffer chronic fading.

Forecast for the next 24 hours

'The forecast for the next 24 hours follows:
Solar activity will be (Very low, Low, Moderate, High, or Very high) .
The geomagnetic field will be (Quiet, Unsettled, Active, Minor storm, Major storm, Severe storm).'

Solar Activity

The quantitative criteria for the solar activity forecast are identical to the 'Conditions for the past 24 hours' portion of the broadcast as explained previously except that the forecaster is using all available measurement and trend information to make as informed a projection as possible. Some of the key elements in making the forecast include the number and types of sunspots and other regions of interest on the sun's surface as well as what kinds of energetic events have occurred recently.

Geomagnetic Activity

The same six standardized terms are used as in the 'Conditions for the past 24 hours' portion of the broadcast with the forecast mainly based on current geomagnetic activity, recent events on the sun whose effects could influence geomagnetic conditions, and longer-term considerations such as the time of year and the state of the sunspot cycle.

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Information by Phone

The Geophysical Alert Broadcast is also available as a telephone recording. This is useful if you cannot hear WWV or WWHV on the air due to poor propagation. The message can be reached by calling (if necessary) the international exchange, then 1 for the United States, followed by (303) 497 3235. This message lasts about 40 seconds, and is updated every 3 hours. If you're trying some long distance listening, and neither WWV nor WWVH are audible in your area, the short call to Boulder may save a lot of time. At off-peak rates it can be very economical, even long-distance.

In Australia, a similar service is offered by the Ionospheric Prediction Service near Sydney. Their propagation message is available free of charge by dialing 61 for Australia, and then 2 269 8614.

Information on the Web

Chances are you have access to the Web. In that case, current solar activity is available on-line. Check our Hitlist for details since this is kept up to date.

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a index. A 3-hourly 'equivalent amplitude' of geomagnetic activity for a specific station or network of stations expressing the range of disturbance of the geomagnetic field. The a index is scaled from the 3-hourly K index according to the following table:

K	0	1	2	3	4	5	6	7	8	9
a	0	3	7	15	27	48	80	140	240	400

x-ray flare class. Ranking of a flare based on its x-ray output. Flares are classified according to the order of magnitude of the peak burst intensity (I) measured at the earth in the 0.1 to 0.8 nm wavelength band as follows:

	Peak, 0.1 to 0.8 nm band
Class	(Watt/square metre)
B	$I < 10^{-6}$
C	10^{-6} $I < 10^{-5}$

M	10^{-5} I < 10^{-4}
X	I 10^{-4}

A multiplier is used to indicate the level within each class. For example:

M6 = 6 X 10^{-5} Watt/square metre

Additional Information Sources

Space Environment Laboratory Computer Bulletin Board

If you have a modem-equipped computer, you can use it to call the Space Environment Laboratory's free computer bulletin board and obtain additional solar and radio propagation-related data. This board operates 24 hours a day, 7 days a week and is located in Boulder, Colorado in the United States. Access is free except for the charges made by your phone company for the call.

The telephone number is 1 for North America, then (303) 497-5000. The communications parameters are as follows: 300, 1200 or 2400 baud; data word protocol is 8-bit/character with 1 stop bit and no parity. The board is completely menu-driven and contains an extensive Help section.

Available material includes HF Propagation Reports based on actual operational experience during the previous several hours, regular Solar Reports which give more extensive data on solar and geomagnetic activity than in the Geophysical Alert Broadcasts, and Maximum Usable Frequency (MUF) predictions based on user-supplied geographic coordinates and existing sunspot numbers. Data on the board is continuously updated from the Space Environment Laboratory's worldwide data base.

NOTE: This computer bulletin board uses the Bell Standard tones for its data communications. Many modems outside the U. S. use other standards (e.g CCITT) so consult your equipment operating instructions before attempting to contact this bulletin board from outside the U. S.

What Next?

If you have any further **specific** questions about propagation, here are some further sources of information:

Space Environment Services Center
NOAA/ERL R/E/SE2
325 Broadway
Boulder, Colorado 80303
U S A

IPS Radio and Space Services,
P.O. Box 702,
Darlinghurst NSW 2010
Australia

Further Reading:

'Proceedings 1991'. Editors: John Bryant, Fritz Mellberg et al. Publisher: Fine Tuning Special Publications, RRT #5, Stillwater OK 74074 USA. Price: US$19.50 cover price plus US$2.00 postage in USA, US$3.00 elsewhere surface mail, US$15.00 airmail.

A board of twelve editors has selected a range of in-depth articles about tropical band propagation, antennas (e.g. the T2FD & the famous Beverage. This project is non-profit making.

Did you find this guide useful? What could be improved? Send your comments to:

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